Empirical Model for Sea Spray Production

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Project Description
Goal: Develop a reliable sea spray source term for global aerosol modeling using satellite microwave radiometers. Method:
- Collocate in situ sea spray production flux measurements with satellite microwave radiometer observations.
- Derive the microwave brightness temperature contribution from ocean surface emission for the collocated observations.
- Develop a parameterization for the sea spray production flux based on the ocean surface brightness temperatures.

Sea Spray Measurements
The Waves, Aerosol and Gas Exchange Study (WAGES) [2] collected 18 months of near-continuous and autonomous turbulent air-sea flux estimates from the research vessel RRS James Clark Ross. Supporting meteorological and sea-state measurements were also made. We use the following measurements from WAGES:
- size-segregated sea spray aerosol concentration,
- wind vector (adjusted to neutral stability at 10 m height),
- sea surface temperature (SST).
The sea spray aerosol concentration was obtained using the Compact Lightweight Aerosol Spectral Probe (CLASP), [1]. After quality control we began with a set of 785 measurements taken between 2010-10-05 and 2013-06-06.

WindSat Description
WindSat is a polarimetric satellite-based microwave imager jointly Sponsored by US Navy and the NPOESS Integrated Program Office; Designed and built by the Naval Research Laboratory (NRL).
- We use the vertical and horizontally polarized channels for this work.

FLIP Experiment 2012
Unique simultaneous in-site measurements of:
- sea spray production
- microwave brightness temperature
- surface foam
- metocean data
Quantitative evidence of relationship between sea spray production and the 10.7 GHz microwave brightness temperatures in the form of $\Delta T_b$ [3] where:
$$\Delta T_b = T_b - T_S$$
where $T_b$ is the microwave brightness temperature at polarization $p$ for a flat ocean surface.

Sea spray production flux parameterized as a function of $\Delta T_b$:
$$F = a(\Delta T_b)^n$$

Data Collection
- We collocate WAGES measurements to WindSat observations within one hour and 50 km.
- One-to-one matchup is obtained by choosing the WAGES measurement closest in time to a WindSat observation.
- We use sea spray production flux measurements with collocated WindSat observations available within one hour and 50 km.
- Total of 30 collocated observations.
- Good agreement between WindSat retrieved wind speed and SST and the in situ measurements from WAGES. RMS differences of 1.1 m/s for wind speed and 1.1 K for SST.

Initial Results

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$$T_{b_N} - T_{b_p} = f((T_S - R_p T_b))$$

where:
- $T_{b_N}$: brightness temperature for p polarization (vertical or horizontal)
- $T_{b_p}$: brightness temperature for p polarization
- $R_p$: isotropic sea surface reflectivity
- $T_S$: sea surface temperature
- $T_C$: cosmic background temperature (≈ 2.7 K)
- $\Omega$: correction for non-specular reflection
- $\tau$: atmospheric transmissivity

To obtain $T_S$ corresponding to those measured during the FLIP experiment we need to remove the atmospheric contribution.
- The NRL WindSat ocean retrieval algorithm [4] retrieves SST, wind vector, precipitable water vapor (PWV) and cloud liquid water (CLW).

$T_{b_N}$ and $T_{b_p}$ have been derived:
- $T_{b_N}$ and $T_{b_p}$ are derived from the upwelling and downwelling temperatures $R_p$, $T_S$, $T_C$.

$R_p$ is calculated as:
$$R_p = (T_S - T_b)/(T_S - T_b + \tau(T_C - T_b))$$

$T_{b_N}$, $T_{b_p}$ and $T_S$ are used to calculate $T_{b_N}$ and $T_C$.

Sources of Uncertainty
- Spatial and temporal mismatch between the WAGES and WindSat measurements.
- WindSat $T_b$ resolution used here is 25 km x 35 km.
- Satellite retrieval also includes land areas.
- Measurement noise in the WindSat $T_b$.
- Errors in the WindSat parameterized function model.
- Measurement errors in the sea spray production flux.

Conclusions
- Good correspondence between WAGES measured and WindSat retrieved wind speed and SST.
- Indication of potential for accurate parameterization of sea spray production flux in terms of microwave brightness temperature from a satellite-based radiometer.
- Satellite measurements would then provide global sea spray source term.

References